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Abstract

We explored the potential of magnetic nanoparticles (MNPs) for manipulation and control of cell functions using magnetic fields. We synthesized several types of MNPs, functionalize their surfaces to make them biocompatible, and bind them to cells. The investigation then focused on two phenomena, magnetoporation and AC magnetic field heating. In the magnetoporation experiments, we applied pulses of a magnetic field gradient to briefly open cell membranes. In the AC magnetic field heating experiments, we raised the local temperature via excitation of the MNPs chosen to maximize dissipative losses, and monitor the effect on cell viability.

Final Report

GRANT #: N00014-01-1-0912

PRINCIPAL INVESTIGATOR: L. J. Martínez-Miranda

GRANT TITLE: Magnetic Nanoparticles for Manipulation and Control of Biological Processes

AWARD PERIOD: 1 October 2001 - 31 May 2004

OBJECTIVE: To look into the possibility of using magnetic nanoparticles (MNPs) for manipulation and control of cell functions using magnetic fields. To study the phenomena of magnetoporation and AC magnetic field heating in the cells.

APPROACH: Several types of Magnetic Nanoparticles (MNPs) are synthetized and their surfaces functionalized to make them biocompatible, and then bind them to cells to study magnetoporation and AC heating. In the magnetoporation experiments, a weak magnetic field is applied to the cell membranes to briefly open them. This is monitored with X-ray scattering, TEM and SEM. In the AC magnetic field heating experiments, the local temperature is raised via excitation of the MNPs chosen to maximize dissipative losses, and monitor the effect on cell viability.

ACCOMPLISHMENTS: We have synthesized a variety of magnetic nanoparticles and tested them with biological systems in vivo to observe the changes that occur in these systems and whether or not they are viable. In the AC magnetic field heating we have found that cells heated to 43°C are more sensitive to chemical and radiation treatment, but when they are heated to 50° C they die. We have explored how thin a layer of gold we need to add to avoid oxidation of the particles, but preserve the particles' ability to either heat the cells or open the cells. We have functionalized the cells with different surface terminations to investigate how they affect the ability of the nanoparticles to either open the cell or heat the cell and also to have specificity in the cells that the nanoparticles target.

We have developed a novel X-ray scattering assay to determine the interaction between the magnetic nanoparticles and the cell membranes, which a label free

method to evaluate these interactions. In collaboration with L. Kurihara (NRL), we have shown the dependence of the ability of the nanoparticle to help rotate and open the cells on the nanoparticle surface functionalization.

CONCLUSIONS: We have performed experiments which preliminarily confirm the role of the nanoparticles in rotating and opening the cell walls without damage to the cell. We have performed experiments to test the role of gold in avoiding oxidation and the use of the gold coated particles in biomedical applications.

SIGNIFICANCE: Our studies have provided information as to how magnetic nanoparticles interact with living cells and how they affect the cells' walls.

AWARD INFORMATION: The PI was named a fellow of the AAAS and awarded a prize for professional achievement in science from Boricua College.

PUBLICATIONS AND ABSTRACTS:

"Gold-coated magnetic Nanoparticles for Biomedical Applications", Min Chen, Saeki Yamamuro, and Sara A. Majetich, J. Appl. Phys. 93, 7551 (2003).

"An X-ray Scattering study of the interactions between magnetic nanoparticles and living cell membranes", Isaac Koh, Bani H. Cipriano, Sheryl H. Ehrman, Darryl N. Williams, Tracey R. Pulliam Holoman , and L. J. Martínez-Miranda, accepted in J. Appl. Phys, 2005.

"Effect of Magnetic Nanoparticles and Their Functionalization on Liquid Crystal Order", L. J. Martínez-Miranda, Kevin Mccarthy, L. K. Kurihara, and A. Noel, under revision in Molec. Cryst. Liq. Cryst, 2005.

"Evaluation of microbial cellular response to inorganic nanoparticles", Darryl N Williams, Sheryl H Ehrman and Tracey R Pulliam Holoman, submitted to Journal of Nanobiotechnology, 2004.

"Biomedical Applications of Magnetic Nanoparticles", International Conference on Materials for Advanced Technologies, Singapore, Dec. 7.

"Biomedical Applications of Magnetic Nanoparticles", United Engineering Foundation Conference on Gas Phase Nanoparticle Synthesis", Il Ciocco, Italy, June 19.

"Effect of Magnetic Nanoparticles and Their Surface Termininations on Alignment of Biological Molecules", L. J. Martinez-Miranda, I. Koh, S. Ehrman and T. Pulliam-Holoman, to be presented April 1, 2005, MRS meeting, San Francisco, CA.